

ELECTRIC TOOTHBRUSH

Technical Field

[0001]

The present invention relates to an electric toothbrush having bristle bundles implanted with a step height (hereinafter, referred to as stepped bristle bundles) at a tip portion.

Background Art

[0002]

There are widely used electric toothbrushes of a linear-motion type including a conversion means for converting a rotational motion of a motor into a reciprocating linear motion of a brush part, an inversion-motion type including a conversion means for converting a rotational motion of a motor into a reciprocating inversion motion of a brush part, a weight-vibration type that rotates an eccentric weight by a motor to vibrate a brush part, and a linear-vibration type that causes a brush part to reciprocate and vibrate by a linear actuator, and others.

[0003]

Meanwhile, there is a widely used method for implanting bristle bundles by which a plurality of brush bristles is bundled, a plain line is arranged at an approximately center of the bundled brush bristles along the direction of the length, the brush bristles are folded along the plain line, and the folded portions of the brush bristles are put into implant holes together

with the plain line and are implanted with the tip portions aligned such that the brush bristles are at the same height from the implant base (hereinafter, referred to as constant-height bristle bundles). In addition, as other methods for implanting bristle bundles using a plain line, there are proposed methods for implanting stepped bristle bundles by which a plurality of brush bristles is bundled, a plain line is arranged around a position shifted in one direction from the approximate center of the bristles along the direction of the length, the brush bristles are folded along the plain line, and the folded portions of the brush bristles are put into implant holes together with the plain line, whereby the bristle bundles are implanted as if the two kinds of brush bristles different in height (length) are provided and the tips of the bristles in one bundle are stepped (for example, refer to Patent Documents 1 to 4).

Citation List

Patent Literatures

[0004]

Patent Document 1: JP-T No. 2010-531181

Patent Document 2: JP-T No. 2012-511944

Patent Document 3: JP-A No. 2012-75725

Patent Document 4: JP-A No. 2010-154900

Summary of Invention

Technical Problem

[0005]

The toothbrushes with the stepped bristle bundles have the disadvantage that the density of the brush bristles at the tip portion becomes lower and the tips of the brush bristles are likely to be elastically deformed, which leads to degradation of performance in cleaning tooth surfaces and tooth necks. In reverse, they have the advantage that the tips of the brush bristles are easy to insert between teeth, which leads to improvement of performance in cleaning the space between teeth, and thus the commercial use of these techniques for manual toothbrushes has been studied.

[0006]

Meanwhile, the applicant of the subject application has examined the use of the stepped bristle bundles in the brush parts of electric toothbrushes, but has found out that the stepped bristle bundles have not sufficiently improved the cleaning performance of the electric toothbrushes of the liner-motion type, inversion-motion type, linear-vibration type, and the like. In addition, the applicant has also found out that the brush parts of these electric toothbrushes have high vibration frequencies relative to large strokes. Accordingly, when the brush bristles vibrate at the positions opposing the space between the teeth during forward motion, the brush bristles contact one of the tooth surfaces adjacent to the space between the teeth and become elastically deformed. Then, when the brush bristles move to the other tooth surface during backward motion, the brush bristles contact the other tooth surface and become elastically deformed before the tips of the brush bristles returns to the original shape between the teeth, and thus the tips of the brush bristles are not fully inserted into the space between the

teeth, thereby causing the problem that the space between the teeth cannot be sufficiently cleaned.

[0007]

An object of the present invention is to provide an electric toothbrush that improves performance in cleaning the space between teeth while maintaining sufficient performance in cleaning tooth surfaces and tooth necks.

Solution to Problem

[0008]

An electric toothbrush according to the present invention includes: a brush part in which bristle bundles are implanted into implant holes in an implant base; a handle part as a handle for operating the brush part; and a vibration generation means that is contained in the handle part to rotate an eccentric weight around an axis along the longitudinal direction of the handle part to vibrate the brush part. The bristle bundles include stepped bristle bundles that are implanted with a step height at tips into the implant holes.

[0009]

The electric toothbrush includes the stepped bristle bundles that are implanted with a step height at the tips in the implant base. Of the stepped bristle bundles, the tips of the high bristle bundles protrude more outward than the tips of the low bristle bundles. Accordingly, the tips of the high bristle bundles are easy to insert into the space between the teeth, thereby improving the performance in cleaning the space between the teeth. In

addition, the electric toothbrush uses the vibration generation means that rotates the eccentric weight around the axis along the longitudinal direction of the handle part to vibrate the brush part, and the tip portion of the brush part vibrates radially around the axis along the longitudinal direction of the handle part in a direction orthogonal to the axial direction of the handle part, almost without having a vibrational component in the axial direction of the handle part. Accordingly, the tips of the high bristle bundles in the stepped bristle bundles mainly vibrate in the space between the teeth when the handle part is not operated for brushing, thereby significantly improving the performance in cleaning the space between the teeth. Further, the electric toothbrush is preferably used by combination of an electric brushing operation and a manual brushing operation. In the manual brushing operation, the stroke of the brush part is large but the vibration frequency is significantly lower than the vibration frequency of the electric toothbrush. Accordingly, the tips of the brush bristles elastically deform at the positions opposing the tooth surface and then return to the original shape at the position opposing the space between the teeth. Therefore, the tips of the brush bristles are fully inserted into the space between the teeth to improve the performance in cleaning the space between the teeth. Of the stepped bristle bundles, the tips of the high bristle bundles are likely to vibrate not only around the base ends of the stepped bristle bundles but also around the positions corresponding to the tips of the low bristle bundles, thereby further improving the performance in cleaning the space between the teeth.

[0010]

It is preferred that the step height in the stepped bristle bundles is set to 1 to 5 mm. When the step height in the stepped bristle bundles is less than 1 mm, the performance in cleaning the space between the teeth can be obtained only to the same degree as that with the use of the constant-height bristle bundles. When the step height in the stepped bristle bundles exceeds 5 mm, the performance in cleaning the space between the teeth becomes lower than that with the use of the constant-height bristle bundles. Accordingly, the steps are preferably set to 1 to 5 mm.

[0011]

It is preferred that the cross sections of the brush bristles in the stepped bristle bundles are formed in a sea-island shape, and the tips of the brush bristles are configured such that a core bristle composed of an island portion protrudes from a sea portion. The use of the thus formed brush bristles improves the performance in cleaning the space between the teeth as compared to the case where the tips of the brush bristles are flat cut.

[0012]

It is preferred that a protrusion length of the core bristle from the sea portion is set to 0.5 to 1.0 mm. When the protrusion length of the core bristles is too short, the performance in cleaning the space between the teeth becomes deteriorated. When the protrusion length of the core bristles is too long, the elasticity of the bristles becomes lower and the performance in cleaning becomes deteriorated with a decrease in usability. Accordingly, the protrusion length is preferably set to 0.5 to 1.0 mm.

[0013]

It is preferred that the brush part composed of only the bristle bundles has a natural vibration frequency approximated to a natural vibration frequency of the main body of the electric toothbrush excluding the brush part. According to this configuration, it is possible to maximize the vibration of the brush part and improve the performance in cleaning the tooth surfaces, the space between the teeth, and the tooth necks.

[0014]

The implant area of the bristle bundles in the implant base can be set to 0.5 cm² or more, and the number of the implant holes can be set to 35 or more. As described above, when the stepped bristle bundles are implanted in the implant base, the density of the brush bristles at the tips decreases by half. Accordingly, it is possible to increase the implant area of the bristle bundles in the implant base to increase the number of the implant holes and maintain the sufficient performance in cleaning the space between the teeth. The implant area of the bristle bundles here refers to the area of a portion surrounded by a straight line circumscribing the implant holes constituting the outer edges of the brush part.

[0015]

It is preferred that at least two columns of the stepped bristle bundles are implanted at the widthwise center of the implant base along the longitudinal direction of the implant base. According to this configuration, the stepped bristle bundles can clean sufficiently the space between the teeth.

[0016]

The stepped bristle bundles and the constant-height bristle bundles with tips aligned can be implanted in the implant base. By implanting the stepped bristle bundles and the constant-height bristle bundles in the same implant base, it is possible to improve the performance in cleaning the space between the teeth by the stepped bristle bundles, and improve the performance in cleaning the tooth surfaces and the boundary portions between the teeth and the gums by the constant-height bristle bundles.

[0017]

It is preferred that the length of the constant-height bristle bundles is set to be equal to the length of low bristle bundles in the stepped bristle bundles. According to this configuration, it is possible to reliably clean the space between the teeth by the stepped bristle bundles.

Advantageous Effects of Invention

[0018]

According to the present invention, the electric toothbrush includes the stepped bristle bundles that are implanted with a step height at the tips in the implant base. Of the stepped bristle bundles, the tips of the high bristle bundles protrude more outward than the tips of the low bristle bundles. Accordingly, the tips of the high bristle bundles are easy to insert into the space between the teeth, thereby improving the performance in cleaning the space between the teeth. In addition, the electric toothbrush uses the vibration generation means that rotates the eccentric weight around the axis along the longitudinal direction of the handle part to vibrate the brush part, and the tip portion of the brush part vibrates radially around

the axis along the longitudinal direction of the handle part in a direction orthogonal to the axial direction of the handle part, almost without having a vibrational component in the axial direction of the handle part. Accordingly, the tips of the high bristle bundles of the stepped bristle bundles mainly vibrate in the space between the teeth when the handle part is not operated for brushing, thereby significantly improving the performance in cleaning the space between the teeth. Further, the electric toothbrush is preferably used by combination of an electric brushing operation and a manual brushing operation. In the manual brushing operation, the stroke of the brush part is large but the vibration frequency is significantly lower than the vibration frequency of the electric toothbrush. Accordingly, the tips of the brush bristles elastically deform at the positions opposing the tooth surface and then return to the original shape at the position opposing the space between the teeth. Therefore, the tips of the brush bristles are fully inserted into the space between the teeth to improve the performance in cleaning the space between the teeth. Of the stepped bristle bundles, the tips of the high bristle bundles are likely to vibrate not only around the base ends of the stepped bristle bundles but also around the positions corresponding to the tips of the low bristle bundles, thereby further improving the performance in cleaning the space between the teeth.

Brief Description of the Drawings

[0019]

Fig. 1(a) is a front view of an electric toothbrush and Fig. 1(b) is a cross-sectional view of Fig. 1(a) taken along line b-b;

Figs. 2(a) to 2(c) are front views of replacement brushes different in arrangement of bristle bundles;

Fig. 3 is a diagram for describing a method for calculating an implant area;

Fig. 4 is an enlarged cross-sectional view of an implant structure of bristle bundles;

Fig. 5(a) is a lateral view of the tip of a brush bristle and Fig. 5(b) is a lateral view of the tip of another brush bristle;

Fig. 6(a) is a perspective view of a brush bristle of a core-sheath structure and Fig. 6(b) is a lateral cross-sectional view of the same;

Fig. 7(a) is a lateral view of a brush bristle of a sea-island structure, Fig. 7(b) is a perspective view of the same, Fig. 7(c) is a lateral cross-sectional view of the same, and Figs. 7(d) and 7(e) are lateral cross-sectional views of brush bristles of other sea-island structures;

Fig. 8 is a graph representing the results of evaluation testing for cleaning performance depending on the presence or absence of stepped bristle bundles;

Fig. 9 is a graph representing the results of evaluation testing for cleaning performance depending on the densities of bristle bundles;

Fig. 10 is a graph representing the results of evaluation testing for cleaning performance depending on different implant areas;

Fig. 11 is a graph representing the relation between the implant areas and the numbers of the implant holes of a commercially-available manual toothbrush and the electric toothbrush of the present invention;

Fig. 12 is a graph representing the relation between the implant areas and the numbers of the implant holes of a commercially-available electric toothbrush and the electric toothbrush of the present invention;

Fig. 13(a) is a photograph of #24 and #25 in a jaw model after brushing with the electric toothbrush of the present invention and Fig. 13(b) is a photograph of #24 and #25 in the jaw model after brushing with a commercially-available manual toothbrush P;

Fig. 14 is a graph representing the results of evaluation testing for cleaning performance of commercially-available manual toothbrushes P and S and the electric toothbrush of the present invention; and

Fig. 15 is a graph representing the results of evaluation testing for cleaning performance depending on the presence or absence of a vibration generation means.

Description of Embodiments

[0020]

An embodiment for carrying out the present invention will be described with reference to the diagrams. In the embodiment, the upper, lower, front, and back sides of an electric toothbrush are defined with reference to the state in which the electric toothbrush is longitudinally placed with a replacement brush facing upward and a brush part facing forward.

[0021]

As illustrated in Fig. 1, an electric toothbrush 1 has a toothbrush body 4 having a brush part 2 and a handle part 3 for manually operating the

brush part 2, a vibration generation means 5 for vibrating the brush part 2, and a battery 6 for driving the vibration generation means 5.

[0022]

The toothbrush body 4 includes the handle part 3 and a replacement brush 10 detachably attached to the handle part 3. An implant base 12 is provided at the upper end portion of a handle 11 of the replacement brush 10. A plurality of implant holes 13 is formed in a predetermined array in the implant base 12. A plurality of bristle bundles 14 is implanted in the implant holes 13. The bristle bundles 14 form the brush part 2. A specific configuration of the brush part 2 will be described later in detail.

[0023]

The handle part 3 will be described. The handle part 3 is provided with a cylindrical casing 21 of an approximately circular cylindrical shape or the like. The upper end portion of the casing 21 is closed by an upper wall 21a. A metallic coupling shaft 22 projecting upward is integrally provided in the center of the upper wall 21a such that the lower half of the coupling shaft 22 is embedded in the upper wall 21a. A reinforcement ring 23 is fitted onto the upper part of the upper wall 21a to receive efficiently a load of the coupling shaft 22 to be applied to the upper wall 21a.

[0024]

The lower end portion of the replacement brush 10 is formed in a cylindrical shape. A holding cylinder 15 is formed in the lower end portion of the replacement brush 10 such that the coupling shaft 22 is detachably fitted into the holding cylinder 15. The holding cylinder 15 is divided into two parts for extension and contraction. The coupling shaft 22 is

sandwiched in the holding cylinder 15 by the elasticity of the material of the replacement brush 10. An engagement groove 22a is formed in the longitudinal middle of the coupling shaft 22. An engagement protrusion 15a capable of engagement with the engagement groove 22a is formed in the holding cylinder 15 of the replacement brush 10. When the coupling shaft 22 is fitted all the way into the holding cylinder 15, the engagement groove 22a engages with the engagement protrusion 15a. In this state, the replacement brush 10 is held by the coupling shaft 22 such that the replacement brush 10 does not easily come off during a brushing operation. For coupling to the coupling shaft 22, the replacement brush 10 may be configured in any known manner. For example, the coupling shaft 22 is inserted into the holding cylinder 15 of the replacement brush 10, and then the replacement brush 10 is rotated at a certain angle such that the replacement brush 10 can be coupled to the coupling shaft 22.

[0025]

A lid member 24 is provided at the lower end portion of the casing 21 for the battery 6 to be put in and taken out. A small-diameter fitting portion 24a protrudes from the upper end portion of the lid member 24 and is detachably fitted into the lower end portion of the casing 21. A seal ring 25 is fitted onto the base of the fitting portion 24a. When the lid member 24 is fixed to the casing 21, the seal ring 25 is pressed and brought into contact with the lower end portion of the casing 21 so that the lid member 24 and the casing 21 are held in a liquid-tight manner.

[0026]

The battery 6 is mounted in the lower part of the casing 21. A motor 30 is mounted in the upper part of the casing 21 such that a rotation shaft 30a is set along the longitudinal direction of the handle part 3. A switch 31 is installed in the casing 21 between the battery 6 and the motor 30 to switch on or off an energizing circuit for the motor 30.

[0027]

The vibration generation means 5 has the motor 30 and an eccentric weight 32 fixed to the upper end portion of the rotation shaft 30a of the motor 30. The motor 30 rotates eccentrically the eccentric weight 32 to vibrate the upper part of the casing 21. The vibration is transferred to the replacement brush 10 via the coupling shaft 22 to vibrate the brush part 2 of the replacement brush 10.

[0028]

The battery 6 driving the motor 30 is a primary battery. Alternatively, the battery 6 may be a secondary battery such as a nickel hydride battery or a lithium ion battery. In the case of using a secondary battery, an induction coil may be incorporated into the lid member 24 such that the secondary battery can be charged in a contactless manner by an external power source.

[0029]

The present invention is characterized in that the electric toothbrush 1 as described above uses stepped bristle bundles 14A as the bristle bundles 14. A configuration of the implant base 12 and the brush part 2 will be described below in detail.

[0030]

An array of the implant holes 13 (array of the bristle bundles 14) formed on the implant base 12 can be set in an arbitrary known manner. Besides the array as illustrated in Fig. 1(a), for example, the arrays illustrated in Figs. 2(a) to 2(c) and any other array can be used. The width of the implant base 12 can be arbitrarily set according to the number of the bristle bundles 14 to be implanted. When the width is too small, a smaller number of the bristle bundles 14 can be implanted, which leads to degradation of performance in cleaning the tooth surfaces and the tooth necks. When the width is too large, the toothbrush becomes smaller in operability in cleaning of the oral cavity. Accordingly, the width is preferably set to 8 to 18 mm.

[0031]

The diameter of the implant holes 13 is preferably set to 1.2 to 1.5 mm, but may be larger than that. When the stepped bristle bundles 14A are implanted in the implant base 12, the density of the brush bristles 16 at the tip portions decreases by half. Accordingly, to increase the implant area of the bristle bundles 14 in the implant base 12 to increase the number of the implant holes 13, and improve the performance in cleaning the tooth surfaces and the tooth necks and maintain sufficiently the performance in cleaning the space between the teeth, the implant area of the bristle bundles 14 in the implant base 12 is preferably set to 0.5 cm² or more. However, considering the operability in cleaning of the oral cavity, the implant area is preferably set between 0.5 cm² and 3.5 cm². In addition, the number of the implant holes 13 is preferably set between 35 and 60, more preferably between 35 and 50. The implant area of the bristle bundles 14 refers to an

area S of the portion surrounded by a straight line L circumscribing the implant holes 13 constituting the outer edges of the brush part 2 as illustrated in Fig. 3.

[0032]

The bristle bundles 14 capable of being implanted in the implant holes 13 may be the stepped bristle bundles 14A and the constant-height bristle bundles 14B configured as described below. Only the stepped bristle bundles 14A may be implanted in the implant base 12 or an arbitrary mixture of the stepped bristle bundles 14A and the constant-height bristle bundles 14B may be implanted in the implant base 12.

[0033]

The stepped bristle bundles 14A are implanted in such a manner as illustrated in Fig. 4 that a plurality of filaments constituting the brush bristles 16 is bundled at tips aligned and is folded at a position shifted in one direction from an approximate center along the longitudinal direction, a plane line 17 is arranged inside the folded portion, and the folded portion of the brush bristles 16 is press-fitted into the implant hole 13 together with the plane line 17 so that two kinds of bristle bundles different in height, that is, high bristle bundles 14AH and low bristle bundles 14AL are formed.

[0034]

The constant-height bristle bundles 14B are implanted in such a manner as illustrated in Fig. 4 that a plurality of filaments constituting the brush bristles 16 is bundled at tips aligned and is folded at an approximate center along the longitudinal direction, a plane line 17 is arranged inside the folded portion, and the folded portion of the brush bristles 16 is press-fitted

into the implant hole 13 together with the plane line 17 so that the bristle bundles are formed at the same height.

[0035]

Only the stepped bristle bundles 14A may be implanted in the implant base 12 or an arbitrary mixture of the stepped bristle bundles 14A and the constant-height bristle bundles 14B may be implanted in the implant base 12. In the case of implanting a mixture of the stepped bristle bundles 14A and the constant-height bristle bundles 14B, the stepped bristle bundles 14A may form two central columns (shown by black circles) and the constant-height bristle bundles 14B may form the two columns on the both sides (shown by white circles) as illustrated in Fig. 1(a), for example. In this case, however, it is preferred that the height of the constant-height bristle bundles 14B is set to be the same as that of the low bristle bundles 14AL, and the tips of the high bristle bundles 14AH protrude from the constant-height bristle bundles 14B and the low bristle bundles 14AL.

[0036]

The height of the low bristle bundles 14AL from the implant base 12 may be set to 5 to 12 mm, and the height of the high bristle bundles 14AH from the implant base 12 may be set to 6 to 13 mm. A step height H between the tips of the low bristle bundles 14AL and the high bristle bundles 14AH is set to 1 to 5 mm, preferably 2 to 4 mm, because, when the step height H is too small, the bristles become low in insertability into the space between the teeth, and when the step height H is too large, sufficient cleaning performance cannot be obtained due to a lack of bristle elasticity.

[0037]

The numbers of the brush bristles 16 of the low bristle bundles 14AL and the high bristle bundles 14AH are the same because the middle of the brush bristles 16 are folded and implanted in the implant holes 13. For example, the numbers of the brush bristles 16 may be set to 7 to 225 and the diameter of the brush bristles 16 may be set to 0.1 to 0.26 mm, preferably 0.15 to 0.2 mm.

[0038]

A method for setting the step height H between the low bristle bundles 14AL and the high bristle bundles 14AH will be described below.

A natural vibration frequency f_n of the brush part 2 not including the implant base 12 can be determined by the following calculation formula:

[0039]

$$f_n = (kn^2/2\pi)\sqrt{(EI/\rho AL^4)} \quad \dots (1)$$

[0040]

kn : Constant corresponding to an eigenvalue

E : Young's modulus of the brush bristles (vertical elastic modulus)

I : Second moment of area (depending on the fourth power of the brush bristle diameter)

A : Cross section area of the brush bristles

L : Length of the brush bristles

ρ : Density of the brush bristles

[0041]

It can be seen from the foregoing equation 1 that the natural vibration frequency of the brush part 2 is significantly higher than the natural vibration frequency of the electric toothbrush 1 excluding the brush

part 2. Accordingly, in order to approximate the natural vibration frequency of the brush part 2 to the natural vibration frequency of the electric toothbrush 1 excluding the brush part 2 to increase the vibration of the brush bristles by resonance, the brush part 2 is preferably configured in such a manner as described below.

- (1) Decreasing the Young's modulus of the brush bristles
- (2) Thickening the brush bristles
- (3) Increasing the step height
- (4) Increasing the specific gravity.

[0042]

Of the foregoing parameters, the ones having large influence on the natural vibration frequency are the cross-section area and the step height H of the brush bristles 16. However, the brush bristles 16 become harder with increase in cross-section area to exert large influence on usability.

Accordingly, the cross-section area has a lower degree of freedom in selecting the parameter because some users prefer soft bristles. It is therefore important to set properly the step height H with relatively less influence on usability. When the step height H is larger, the natural vibration frequency of the brush part 2 comes closer to the natural vibration frequency of the electric toothbrush 1 excluding the brush part 2. However, when the step height is too large, the stiffness of the brush bristles becomes lower to deteriorate the cleaning performance.

Accordingly, the step height H is preferably set to 1 to 5 mm, preferably 2 to 4 mm.

[0043]

The material for the brush bristles 16 may be any of publicly known synthetic resins for brush bristles of toothbrushes, including: a polyamide resin such as nylon or aramid; a polyester resin such as polybutylene terephthalate (PBT), polypropylene terephthalate (polytrimethylene terephthalate, PPT, or PTT), or polyethylene terephthalate (PET); or a polyolefin resin such as polypropylene (PP) or polyethylene (PE).

[0044]

The brush bristles 16 may be tapered, but in this case, they are lower in elasticity and performance of cleaning the space between the teeth. Accordingly, the brush bristles 16 are preferably formed in a flat-cut shape by cutting in a direction orthogonal to the longitudinal direction as illustrated in Fig. 5(a), or in a rounded-end shape by rounding the tips of the brush bristles 16 in a hemispherical form as illustrated in Fig. 5(b). However, any tip shape other than the foregoing known ones can also be employed.

[0045]

The brush bristles 16 may be brush bristles composed of monofilaments of a single synthetic resin, or may be brush bristles 16A and 16B composed of composite monofilaments of a plurality of synthetic resins having a core-sheath structure or a sea-island structure. In the case of using the brush bristles 16A and 16B having a core-sheath structure or a sea-island structure, core portions 16a and island portions 16c may be exposed at the tips of the brush bristles 16A and 16B.

[0046]

The brush bristles 16A having a core-sheath structure are brush bristles composed of composite monofilaments configured such that a core portion 16a in the center is surrounded by a sheath portion 16b on the outer periphery as illustrated in Fig. 6. The brush bristles 16A are formed by extruding synthetic resin materials for the core portion 16a and the sheath portion 16b from dies at the same time such that the lateral cross sections of the brush bristles 16A are the same at arbitrary positions.

[0047]

The core portion 16a may be formed from a material with a polyamide resin such as nylon or aramid as the main ingredient. The sheath portion 16b may be formed from a material with a polyester resin such as polybutylene terephthalate as the main ingredient.

[0048]

A core bristle 18 composed of the core portion 16a protrudes from the tip of the brush bristle 16A as illustrated in Fig. 6(a). To protrude the core bristle 18, for example, a polyamide resin is used to form the core portion 16a, a polyester resin such as PBT is used to form the sheath portion 16b, and the tip of the brush bristle 16A is immersed in a solution of alkaline chemical such as a caustic soda (NaOH) to expose the core portion 16a and form the brush bristle 16A with the core bristle 18 protruded from the tip. Besides the chemical method, the sheath portion 16b may be removed by a mechanical method.

[0049]

An outer diameter b2 of the sheath portion 16b is preferably set to 0.16 to 0.25 mm. An outer diameter b1 of the core portion 16a is set to

preferably 40 to 90%, more preferably 60 to 80% of the outer diameter of the sheath portion 16b. An exposure length of the core bristle 18 from the sheath portion 16b is preferably set within a favorable range of 0.5 to 1.0 mm.

[0050]

The brush bristles 16B having a sea-island structure are brush bristles composed of composite monofilaments configured such that three island portions 16c are arranged at apexes of a triangle and a sea portion 16d is formed to surround the three island portions 16c as illustrated in Figs. 7(a) to 7(c), or brush bristles composed of composite monofilaments configured such that two island portions 16c are spaced from each other and the sea portion 16d is formed to surround the island portions 16c as illustrated in Fig. 7(d), or brush bristles composed of composite monofilaments configured such that four island portions 16c are arranged at apexes of a square and the sea portion 16d is formed to surround the island portions 16c as illustrated in Fig. 7(e). The brush bristles 16B are formed by extruding synthetic resin materials for the island portions 16c and the sea portion 16d from dies at the same time such that the lateral cross sections of the brush bristles 16B are the same at arbitrary positions.

[0051]

The island portion 16c may be formed from a material with a polyamide resin such as nylon or aramid as the main ingredient. The sea portion 16d may be formed from a material with a polyester resin such as polybutylene terephthalate as the main ingredient.

[0052]

Core bristles 18 composed of the island portions 16c protrude from the tip of the brush bristle 16B as illustrated in Figs. 7(a) and 7(b). To protrude the core bristles 18, for example, the brush bristle 16B having a sea-island structure in which a polyester resin is used to form the sea portion 16d and a nylon resin is used to form the island portions 16c is immersed in a caustic soda (NaOH) solution. The brush bristle 16B is then removed from the caustic soda to dissolve and remove the sea portion 16d from the tip and expose the island portions 16c. Accordingly, the brush bristle 16 can be produced such that the plurality of core bristles 18 protrude from the tip of the sea portion 16d constituting the outer surface of the brush bristle 16. In this case, the tapered shape of the tip of the sea portion 16d and the exposure length of the core bristles 18 can be adjusted as appropriate by the concentration of the caustic soda, the immersion time, the speed of removal from the caustic soda, and the like.

[0053]

The diameter of the sea portion 16d is preferably set to 0.150 to 0.300 mm. The diameter of the core bristles 18 is preferably set to 0.03 to 0.07 mm. The exposure length of the core bristles 18 is preferably set within a favorable range of 0.5 to 1.0 mm.

[0054]

The lateral cross-section shape of the brush bristles may be any other shape other than a circle. In addition, the brush bristles different in lateral cross-section shape may be arbitrarily mixed or the brush bristles of monofilaments and the brush bristles of composite monofilaments may be mixed.

[0055]

The electric toothbrush 1 is intended to brush teeth while vibrating the brush part 2 by the vibration generation means 5. The electric toothbrush 1 is preferably configured to perform a brushing operation in combination with a manual brushing operation. According to this configuration, the motor 30 for the vibration generation means 5 can be small in size with relatively low power, and the handle part 3 of the electric toothbrush 1 can be slim with a small diameter to make the electric toothbrush 1 suitable for a manual brushing operation. Accordingly, the motor 30 for the vibration generation means 5 can be small in size with relatively low power while enhancing the performance of a manual brushing operation, thereby achieving sufficient brushing performance. In addition, the provision of the stepped bristle bundles 14A decrease the density of the brush bristles 16 at the tip portion of the brush part 2 to make it easy to insert the brush bristles 16 into the space between the teeth, thereby improving the performance in cleaning the space between the teeth. Further, by setting the low bristle bundles 14AL of the stepped bristle bundles 14A and the constant-height bristle bundles 14B at the same height, the performance in cleaning the tooth surfaces and the tooth necks can be sufficiently achieved. Moreover, as illustrated in Fig. 4, the bristle bundles 14 of the constant-height bristle bundles 14B tend to vibrate mainly at and around the base end portions P1 of bristle bundles 14 protruding from the implant base 12, whereas the tips of the high bristle bundles 14AH of the stepped bristle bundles 14A are likely to vibrate not only at the base end portions P1 of the stepped bristle bundles 14A but also at and around

positions P2 corresponding to the tips of the low bristle bundles 14AL. This further improves the performance in cleaning the space between the teeth.

[0056]

Next, evaluation testing of the electric toothbrush 1 with the stepped bristle bundles 14A will be described.

[0057]

(Evaluation testing for cleaning performance depending on the presence or absence of a step height)

Eighteen brush bristles 16 configured as shown in Table 1 were folded in the middle and implanted together with plain lines 17 into the 48 implant holes 13 in the implant base 12 illustrated in Fig. 1 in lengths described in Table 1, thereby to produce replacement brushes of Examples 1 and 2 and Comparative Examples 1 and 2.

[0058]

Then, a jaw model (produced by Nissin Dental Products Inc.) was prepared. Occlude (produced by Pascal Company Inc.) was applied as artificial dental plaque to the left maxillary second premolar (#25) and the left maxillary first molar (#26) in the jaw model. The left maxillary second premolar (#25) and the left maxillary first molar (#26) were brushed under brushing conditions shown in Table 2 by the electric toothbrushes 1 with the replacement brushes of the Examples 1 and 2 and the Comparative Examples 1 and 2. Then, the left maxillary second premolar (#25) and the left maxillary first molar (#26) were photographed from the lateral side. The images were subjected to image analysis to calculate the rates of

removal of plaque from a specific area in the space between the teeth. Table 1 and Fig. 8 show the results of the calculations.

[0059]

[Table 1]

	Example 1	Comparative Example 1	Example 2	Comparative Example 2
Structure of brush bristles	Sea-island structure (three island portions)	Monofilaments		
Material	Sea poriton: Unsaturated polyester resin Island portion: Nylon	Nylon	Nylon	Nylon
Step height	3 mm	None	3 mm	6 mm
Diameter of brush bristles	0.2 mm	0.19 mm	0.19 mm	0.19 mm
Bristle height	(High) 12 mm (Low) 9 mm	12 mm	(High) 12 mm (Low) 9 mm	(High) 12 mm (Low) 6 mm
Removal rate of plaque from space between teeth	58%	44%	52%	35%

[0060]

[Table 2]

Brushing conditions	
Brushing pressure	200 g
Stroke	20 mm
Brushing portions (FDI method)	Left maxillary second premolar (#25) Left maxillary first molar (#26)
Brushing time	10 sec
Brushing speed	150 rpm
Presence or absence of vibrations	Present (1.5 V)

[0061]

It can be seen from Table 1 and Fig. 8 that the replacement brushes of the Examples 1 and 2 having the stepped bristle bundles with a step height of 3 mm are higher in performance in cleaning the space between the teeth than the replacement brush of the Comparative Example 1 having the

stepless constant-height bristle bundles. In addition, it can be understood that the Comparative Example 2 with a step height of 6 mm is lower in cleaning performance than the Comparative Example 1 without a step height, and the step height is preferably set to be less than 6 mm.

[0062]

(Evaluation testing for cleaning performance depending on the density of the bristle bundles)

The use of the stepped bristle bundles decreases the density of the bristle bundles at the tip portion of the brush part. Accordingly, the following testing was carried out to investigate changes in cleaning performance due to decrease in the density of the bristle bundles at the tip portion of the brush part.

[0063]

A replacement brush with an implant base of the same dimensions as those of the Example 1 and without brush bristles was used. Brush bristles of the same sea-island structure as that of the Example 1 were implanted into 48 implant holes of six columns in the replacement brush such that no step height was formed. As Comparative Example 4, a replacement brush was produced in the same manner as the replacement brush of the Comparative Example 3, except that the implant holes of the second column from the outside were removed from the replacement brush of the Comparative Example 3 so that bristle bundles were implanted into 32 implant holes of four columns. As Comparative Example 5, a replacement brush was produced in the same manner as the replacement brush of the Comparative Example 3, except that the implant holes of the second column

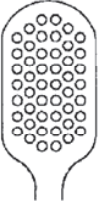
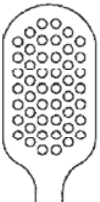
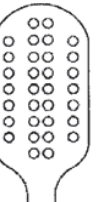
from the outside were removed and the implant holes of the remaining four columns were alternately removed from the replacement brush of the Comparative Example 3, so that bristle bundles were implanted into eighteen implant holes of four columns.

[0064]

The electric toothbrushes 1 with the replacement brushes of the Example 1 and the Comparative Examples 3 to 5 were subjected to evaluation testing by the same method as the evaluation testing for cleaning performance depending on the presence or absence of a step height described above. Table 3 and Fig. 9 show the results of the evaluation testing.

[0065]

[Table 3]

		Example 1	Comparative Example 3	Comparative Example 4	Comparative Example 5
Structure of brush		Sea-island structure (three island portions: three bristles)			
Material		Sea portion: Unsaturated polyester resin Island portion: Nylon			
Diameter of brush		0.2 mm			
Step height		3 mm	None		
Bristle height		(High) 12 mm (Low) 9 mm	12 mm		
Array of implant holes		Six columns	Six columns	Two columns removed	Scattered
					
Removal rate of plaque	Tooth surface	94%	78%	77%	48%
	Space between teeth	58%	19%	29%	16%
	Tooth neck	98%	85%	76%	82%

[0066]

It can be seen from Table 3 and Fig. 9 that, even when the brush bristles composed of composite monofilaments having the same sea-island structure are used, the Example 1 having the stepped bristle bundles with a step height of 3 mm is higher than the Comparative Example 3 in the ratio of removal of plaque from not only the space between the teeth but also the tooth surfaces and the tooth necks. The Example 1 in which the brush bristles are sparse only at the tip portion of the brush part is higher than the Comparative Examples 4 and 5 in which the brush bristles are sparse at the entire brush part, in the ratio of removal of plaque from all of the tooth surfaces, the space between the teeth, and the tooth necks.

[0067]

(Evaluation testing for cleaning performance depending on differences in implant area)

As Comparative Examples 6 to 8, three replacement brushes were produced such that the implant areas, the numbers of the implant holes, and the arrays of the bristle bundles were as shown in Table 4.

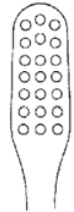
[0068]

The electric toothbrushes 1 with the replacement brushes of the Comparative Examples 3 and 6 to 8 were subjected to evaluation testing by the same method as the evaluation testing for cleaning performance depending on the presence or absence of a step height described above.

Table 4 and Fig. 10 show the results of the evaluation testing.

[0069]

[Table 4]

	Comparative Example 6	Comparative Example 7	Comparative Example 3	Comparative Example 8
Structure of brush	Sea-island structure (three island portions: three bristles)			
Material	Sea portion: Unsaturated polyester resin Island portion: Nylon			
Diameter of brush	0.2 mm			
Step height	None			
Bristle height	12 mm			
Array of implant holes	Three columns	Five columns	Six columns	Seven columns
				
Number of implant holes	19	39	48	49
Implant area (cm ²)	1.12	2.09	2.2	2.8
Removal rate of plaque	Tooth surface	91%	83%	78%
	Space between teeth	54%	25%	19%
	Tooth neck	95%	83%	85%

[0070]

It can be seen from Table 4 and Fig. 10 that, when the columns of the implant holes increases in number, the brushing pressure is distributed to decrease the load applied to each of the brush bristles, thereby reducing the removal ratio of plaque as a whole.

[0071]

(Comparison with commercialized products)

Fig. 11 is a graph representing the relation between the implant areas and the numbers of the implant holes of a commercialized manual toothbrush and the electric toothbrush of the present invention. In the graph, the region surrounded by a one-dot chain line indicates a range of implant area and the number of implant holes applicable to the electric toothbrush of the present invention. Fig. 12 is a graph representing the

relation between the implant areas and the numbers of the implant holes of a commercialized electric toothbrush and the electric toothbrush of the present invention. In the graph, the region surrounded by a one-dot chain line indicates a range of implant area and the number of implant holes applicable to the electric toothbrush of the present invention.

[0072]

It can be seen from Figs. 11 and 12 that the range of implant area and the number of implant holes applicable to the electric toothbrush of the present invention partially overlaps that of the commercialized manual toothbrush but does not overlap that of the commercialized electric toothbrush.

[0073]

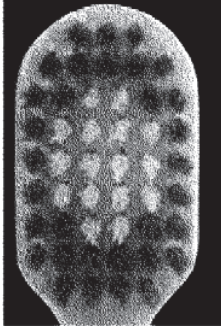
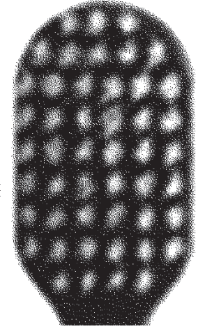
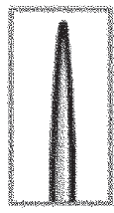
(Evaluation testing for cleaning performance in comparison with commercialized manual toothbrushes)

As commercialized manual toothbrushes, commercialized manual toothbrushes P and S as shown in Table 5 were used.

The electric toothbrushes 1 with the replacement brush of the Example 1 and the commercialized manual toothbrushes P and S were subjected to evaluation testing by the same testing method as the evaluation testing for cleaning performance depending on the presence or absence of a step height described above. Figs. 13 and 14 show the results of the evaluation testing.

[0074]

[Table 5]

Commercialized products P and S		
	Commercialized product P	Commercialized product S
		
Head width (mm)	15.1 (catalog description: 14.7)	14.7 (catalog description: 14.4)
Head length (mm)	24.8	24.5
Hole diameter (mm)	$\phi 1.5$	$\phi 1.5$
Implant area (cm ²)	2.5	2.52
Number of holes	48	48
Bristle height (mm)	(High) 12.5 (Low) 8.5	12.5
Filament diameter (mm)	(Gray) 0.182 (White) 0.161	0.18
Material	Saturated polyester resin	Saturated polyester resin
Bristle tip	High bristle  Ultra-tapered Low bristle  Flat bristle	 Ultra-tapered bristle

[0075]

It can be seen from Figs. 13 and 14 that the electric toothbrush 1 with the replacement brush of the Example 1 is higher than the commercialized manual toothbrushes P and S in the ratio of removal of

plaque from all of the tooth surfaces, the space between the teeth, and the tooth necks.

[0076]

(Evaluation testing for cleaning performance depending on the presence or absence of electromotion)

The electric toothbrush 1 with the replacement brush of the Example 1 was used. The electric toothbrush 1 was subjected to evaluation testing for cleaning performance depending on the presence or absence of vibrations caused by a vibration generation means, by the same testing method as the evaluation testing for cleaning performance depending on the presence or absence of a step height described above except that the brushing pressure was set to 100g and the stroke was set to 15 mm. Fig. 15 shows the test results.

[0077]

It can be seen from Fig. 15 that manual brushing with vibrations applied to the replacement brush by the vibration generation means was higher than mere manual brushing in the ratio of removal of plaque from all of the tooth surfaces, the space between the teeth, and the tooth necks.

[0078]

An embodiment of the present invention has been described so far. However, the present invention is not limited to the embodiment described above but can be modified without deviating from the gist of the present invention.

Reference Signs List

[0079]

- 1 Electric toothbrush
- 2 Brush part
- 3 Handle part
- 4 Toothbrush main body
- 5 Vibration generation means
- 6 Battery
- 10 Replacement brush
- 11 Handle
- 12 Implant base
- 13 Implant hole
- 14 bristle bundle
- 14A Stepped bristle bundle
- 14AH High bristle bundle
- 14AL Low bristle bundle
- 14B Constant-height bristle bundle
- 15 Holding cylinder
- 15a Engagement protrusion
- 16 Brush bristle
- 16A Brush bristle
- 16B Brush bristle
- 16a Core portion
- 16b Sheath portion
- 16c Island portion
- 16d Sea portion

17	Plane line
18	Core bristle
21	Casing
21a	Upper wall
22	Coupling shaft
22a	Engagement groove
23	Reinforcement ring
24	Lid member
24a	Fitting portion
25	Seal ring
30	Motor
30a	Rotation axis
31	Switch
32	Eccentric weight
b1	Outer diameter
b2	Outer diameter
H	Step

CLAIMS:

1. An electric toothbrush, comprising:
 - a brush part in which bristle bundles are implanted into implant holes in an implant base;
 - a handle part as a handle for operating the brush part; and
 - a vibration generation means that is contained in the handle part to rotate an eccentric weight around an axis along the longitudinal direction of the handle part to vibrate the brush part, wherein
 - the bristle bundles include stepped bristle bundles that are implanted with a step height at tips into the implant holes.
2. The electric toothbrush according to claim 1, wherein the step height in the stepped bristle bundles is set to 1 to 5 mm.
3. The electric toothbrush according to claim 1 or 2, wherein
 - the cross sections of the brush bristles in the stepped bristle bundles are formed in a sea-island shape, and
 - the tips of the brush bristles are configured such that a core bristle composed of an island portion protrudes from a sea portion.
4. The electric toothbrush according to claim 3, wherein a protrusion length of the core bristle from the sea portion is set to 0.5 to 1.0 mm.

5. The electric toothbrush according to any one of claims 1 to 4, wherein the brush part composed of only the bristle bundles has a natural vibration frequency approximated to a natural vibration frequency of the main body of the electric toothbrush excluding the brush part.

6. The electric toothbrush according to any one of claims 1 to 5, wherein the implant area of the bristle bundles in the implant base is set to 0.5 cm² or more, and the number of the implant holes is set to 35 or more.

7. The electric toothbrush according to any one of claims 1 to 6, wherein at least two columns of the stepped bristle bundles are implanted at the widthwise center of the implant base along the longitudinal direction of the implant base.

8. The electric toothbrush according to any one of claims 1 to 7, wherein the stepped bristle bundles and constant-height bristle bundles with tips aligned are implanted in the implant base.

9. The electric toothbrush according to claim 8, wherein the length of the constant-height bristle bundles is set to be equal to the length of low bristle bundles in the stepped bristle bundles.